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WELCOME TO THE SACLAY PROPELLER TESTING CENTER

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16. Abstract This article describes the history, organization, purpose, and activities of the Saclay Propeller Testing Center. A list is provided of all facilities, current and planned, and a summary of the types of tests done in each facility is given.

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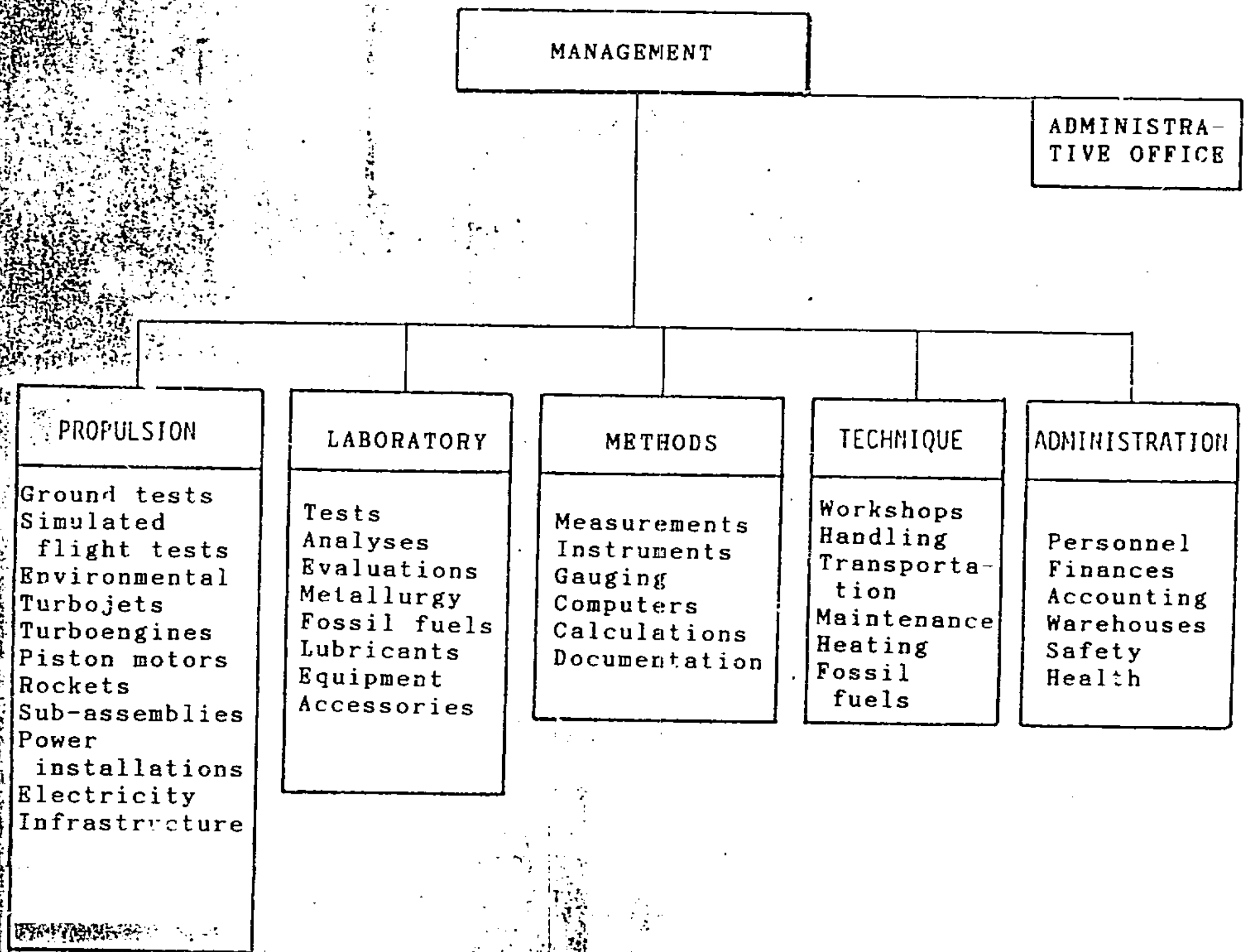
GENERAL ORGANIZATION



WELCOME TO THE SACLAY PROPELLER TESTING CENTER

INTRODUCTION /1*

The origins of the present Propeller Testing Center go back virtually to the birth of the aviation engine industry in France. In fact, these engines, probably more than any others, must meet precise operating performance and safety characteristics (specifications). This is why the Chalais-Meudon testing station, where "official" engine quality control tests are executed, was created during the First World War.

But the facilities installed at Orléans-Briey as of the end of 1939, with the first altitude chamber for piston engines, constituted the large Testing Center necessary for a rapidly expanding engine industry.

Remember that after this Center was bombed in 1940, the personnel and certain materials regrouped in the country (mainly at Saint-Etienne) and then again at Chalais-Meudon. After 1947 the Saclay site was occupied via Villeras. Since 1950, turbines have been tested there, and in 1956 the CEMH flight simulation chambers began operation.

Due to considerable French investments concentrated on this one Center, it is able to fulfill essentially two purposes:

- one for Official Service involving quality control and conformity to technical requirements or regulations;

- one industrial, involving execution of the multiple tests necessary for introducing new and modern engines.

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*Numbers in the margin indicate pagination in the foreign text.

There are more powerful centers in the United States (and no doubt in the USSR), but the PTC [Propeller Testing Center], with the British N.G.T.E. [expansion unknown], gives European industry an effective capacity to produce competitive engines, whether military or private.

CHARACTERISTICS OF THE PTC /2

STATUS

Establishment of the General Armament Delegation of the Ministry of Defense (Technical Administration of Aeronautic Construction).

Director: General Engineer L. Pacaud

Direct administration establishment (budgetary schedule).

LOCATION

On the north bank of the Etangs at Saclay, between the borough of Saclay and the district of Val d'Albian. Served by the F18 rapid transit line which links the Sevres Bridge (Paris exit) to the Orléans and Chartres expressway ("Vauhallan - Test Center" exit).

Mailing address: C.E.Pr - SACLAY F - 91406 ORSAY CEDEX

Telephone: (1) 941.81.50. Telex: 692 148 F TURBAIR

PURPOSE

Official approval tests on aircraft propellers required by the Investment Services of the D.G.A. [expansion unknown].

Development for the aeronautics industry of testing methods which simulate flight conditions and engine operation.

ACTIVITY

Applied research tests (DRET - ONERA - Builders).

Introductory tests on prototypes from sub-assemblies and parts to complete engines (SNECMA - TURBOMECA - MICRO-TURBO - etc.).

Flight environment tests: icing, various types of ingestion for the benefit of engine and aircraft builders (cell elements).

Development tests for complete engines and sub-assemblies.

Tests for quality, endurance, load portion.

Tests for certification of private devices.

Environment tests on various materials, ground or ballistic.

Quality tests on fossil fuels, lubricants, equipment, and engine control instruments.

Analyses and controls: metallurgical and on organic products.

Studies of propellers or structures during inquiries after accidents (military and private aircraft).

METHODS

/3

Personnel - 1030, of which 29 are military engineers, 27 are private engineers, 155 are technicians, 114 are administrative, and 705 are government workers.

Facilities - Actualized value in 1977 of about 2,500 MF.

Area - About 100 ha, of which 22 ha are in use.

Steam power produced on site - 150 mW; thermal - 75 mW.

Pumping capacity - 50,000 m^3/hr.

TESTING FACILITIES

4 simulated flight chambers up to Mach 2
3 simulated flight chambers, turbo and stato jets, up to Mach 4
2 compressors (one of which, 40 mW, is under construction)
2 altitude stands for turboengines with brakes
4 combustion sections at more than 25 bars
1 large flow combustion section, 2 models
1 stand of hot turbines
2 ground stations with kinetic heat simulation
1 ground station for large turbofans with reverse
2 ground stations for turboprops with blades, automated
4 ground stations for turboengines with brakes, automated
2 ground stations for medium turbojets
2 solid fuel rocket testing chambers (Ø 2 m) in altitude
1 station for fuel circuits in extreme conditions
1 station for oligocyclic disc fatigue (under construction)
1 site for tests on ingestion of and impact by birds and hailstones on complete engines and fixed guide vanes

1 soundproof 600-m^3 chamber and 1 anechoic wind tunnel Ø 3 m
1 1000-m^3 climatic hangar (vehicles, aircraft, helicopters)
2 acoustic fatigue cells at 150/155 dB
2 automatic thermal fatigue streams
4 machines for oligocyclic fatigue in heat on gauges
1 scanning electron microscope and 1 for transmission
Laboratories for metallurgy, chemistry, spectrometry
Workshop for engine disassembly

EXAMPLES OF TESTS

Military engines
Endurance and performance of the M-53 above Mach 2
Cold starts of the Larzac and the complete Alphajet
Oligocyclic fatigue of the Adear, the Bastan, the Tyne
Performance and endurance of the AMX vehicle power groups

Private engines
Behavior of the Olympus on the Concorde program
Analysis of gases emitted in supersonic flight
Certification in icing of the Mercury nacelle (JT SD engine)
Ingestion of birds and hailstones by the CFM 56 engine

THE CFM 56 IN STATION T1 /4

STATION T1

Put into operation in 1970, it is a "ground" station capable of working with large jets (800 kg/s air flow). A high measurement capacity allows it to conduct all currently known types of tests.

From 1971 to 1974 the T1 station was used for the Concorde and made it possible to test a complete TRA-type afterbody

with two Olympus engines operating simultaneously.

In 1975 it was equipped to receive the CFM 56 in a suspended position.

Its principal characteristics are the following:

- 10 x 10 m test section - balance of 25,000 daN,
- 900 measurements per 6 seconds and 100 dynamic measurements recorded,
- local Mitra 15 computer,
- lateral recovery equipment for reverse jets.

THE CFM 56 TESTS

Since July 1976, prototype No. 1 has undergone many tests:

- performance evaluation in various configurations,
- operation with thrust inversion,
- compressor field and mismatch,
- preparation of flights on Caravelle and YC 15,
- simulation of crosswind and influence of aerodynamic distortions on the various components.

An average of 30 hours of testing is done each month, which leads to the interpretation of about 500,000 measurements.

In 1977 another engine will undergo a series of various development tests. Then the station will be prepared for the type certification test.

Purpose of the station: The TX station is a site which specializes in tests and studies on ingestion or retention. Two concrete areas, one for shooting at fixed targets and the other for shooting at a complete engine, use the same test methods (cannons, high-speed cameras, measurement equipment, and equipment for recording stress and vibration).

1. Fixed target shooting area. Covered area (18 x 6 m) for the study of impact mechanics:

   - Resistance to perforation of materials (studies on plating, retention of engine gear-boxes, etc.);

   - Resistance and mechanics of shock for engine components: guide vanes; air intake systems; cowling that turns when hail, birds, or chunks of ice are ingested.

2. Engine shooting area. This open-air test station has many uses. To permit engine testing without annoyance, it is soundproofed with anti-noise walls.

   Principle types of tests:

   - Ingestion of birds (from 110 to 1800 g) at takeoff speed;
   - Ingestion of hailstones of Ø 25 mm or 50 mm, at flight speed in turbulent air;
   - Retention: in takeoff mode the departure of a blade is controlled pyrotechnically;
   - Ingestion of ice chunks of various sizes (failure of the air intake de-icing system).

Principle tests:

- CFM 56 Engine (Shooting five 700-g birds and two ice chunks measuring 150 x 100 x 25 mm in November 1975):

  - Ingestion of hail: shooting 50 hailstones Ø 25 and 50 mm planned for July 1977;
  - Ingestion of birds: shooting seven birds (700 g) planned for October 1977;
  - Retention: Controlled departure of a fan blade planned for January 1978.

- ASTAFAN Turboméca Engine: Certification test (shooting two 700-g birds) in November 1976.

Principle equipment:

- Compressed air cannons for all types of projectiles. The shot is fired by pyrotechnically rupturing a flexible membrane;
- High-speed cameras (3000 pictures/second);
- Linked to a computer, the station is capable of 600 measurements on performance and can record parameters continuously.

ANECHOIC WIND TUNNEL - CEPRA 19 /6

UTILIZATION

Acoustic measurements with simulation of source advancement speed.

PRINCIPLE

Wind tunnel with continuous open stream in a circuit and isolated from parasitic vibrations and noises.

SUMMARY DESCRIPTION

In order, from upstream to downstream:

- a huge entrance muffler (area 9 x 9 m; total length 9 m);

- a quarter-sphere circuit (interior radius: 9.6 m) internally covered with a glass wool prism and containing:

  . a section with variable configuration - for example, 2 m diameter and 8 m length,
  . a hot compressed air entrance for jet noise tests,
  . a microphone which can move anywhere in the chamber and which is linked to a system for real-time interpretation of data, which includes a Mitra 15 computer.

  This circuit rests on reinforced rubber supports, designed to nullify vibrations from the ground.

- an intermediary muffler to isolate the test room from the feeding system;

- a centrifuge ventilator with constantly changeable rotation speed which feeds a 7-mW electric motor through a hydraulic coupler;

- an exit muffler.

PLANNED CAPABILITIES

- Cut-off frequency in the anechoic chamber below 200 Hz;
- Speed above 100 m/s in a section 2 m in diameter, or of about 70 m/s in a section of 3 m;
- Supply of models with jets at 1350°K under 6 bars.

START-UP

Begins operation in March 1977. Dedication on May 6, 1977 by the General Representative for Armament. Industrial studies planned as of the 4th trimester.

FLIGHT SIMULATION /7

Modern aircraft are being developed in a vast range of altitudes and speeds. The air around them can be hotter or colder depending upon the season and the latitude; its pressure decreases rapidly with altitude.

Due to the effect of kinetic recompression produced in the air intake hose, the engine can be supplied with air at a pressure and temperature much higher than on the ground, whereas at its exit the air is at ambient pressure, which is lower than ground pressure.

Flight simulation in ground installations consists of reproducing this configuration in "chambers" which are airtight circuits divided into two compartments: upstream, air is brought to the temperature and pressure conditions obtained in the aircraft's air intake; downstream, the pressure which corresponds to flight altitude is maintained. The engine is placed between the two compartments, generally on a support which permits measurement of thrust.

At the PTC, the highest capacity chamber, R5, 5.5 m in diameter and 35 m long, can admit air at 7 bars and 650°C, while at the exit it is at 0.05 bars, or an altitude of 20.6 km. It is thus possible to simulate flight at Mach 4.

After making it possible to test the Olympus for the entire Concorde flight program, including takeoff, this chamber was returned to the M-53 engine, for which it is very well adapted.

Flight simulation in a chamber requires certain heavy installations. But they are multi-purpose and of guaranteed longevity. With respect to real flight, the advantages are numerous:

- possibility of testing an engine from the first stages of development when it is not yet trustworthy enough for real flight;

- possibility of reaching the entire range of future flight even when an aircraft with corresponding capabilities does not yet exist (supersonic);

- possibility of a very large number of simultaneous measurements;

- complete matrix of any flight condition combination (pressure and temperature) any time of year;

- possibility of using equipment which is still in the model stage with the engine;

- possibility of simulating breakdowns realistically.

However, by virtue of its own characteristics and requirements, the real flight test remains necessary because this

is when new problems are found.

THE 2 X 25 MW CA/CB CENTER /8

This center was dedicated on December 11, 1973, and began operation in 1971.

Characteristics. It is essentially an air compression center whose power is supplied by:

- 2 steam boilers (63 bar, 490°C), each supplying 110 t/h;
- 2 connected turbines which can develop 25 mW between 3500 and 4600 t/mn.

Each group supplies a group of turning machines:

- Line CB, composed of 4 axial compressors, nominal ratio of over 7;
- Line CA, composed of 2 identical compressors and an expansion turbine ("TDA"), ratio of 7 to 2 axial stages.

Air treatment uses 6 water cooling areas and 1 90-ton aluminum dryer. Combustion gases cross two cooling areas, 6 m long and 5 m in diameter, and 2 water separators. A huge muffler was placed at the escape point for back gusts under pressure.

Use. This assembly is used to supply engines in simulated flight testing in the chambers and to suction combustion gases at low pressure and return them to the atmosphere. The TDA turbine can furnish cold air (-65°C) or recover power from hot compressed air, which makes it possible to supply the 40-mW compressor station under construction (station C3). The table below summarizes the various possible configurations:

		CB	CA	TDA
SUPPLY OF TEST STATIONS	HOT COMPRESSED AIR	X or	X	
	COLD COMPRESSED AIR		X and	X
AVERAGE SUCTION	ALTITUDE (less than 45,000 ft)	X or	X	
INCREASED SUCTION	ALTITUDE	X and	X	
SUPPLY OF THE C3 STATION		X and	X and	X

Capabilities.

Hot compressed air	95 kg/s	7 bars	60° to 300°C
Cold air	95 kg/s	1 bar	-65°C
Suction (CB)	50 kg/s	0.15 bar	
(CB-CA)	10 kg/s	0.03 bar	

THE MEASUREMENT CENTER /9

Testing requires precise, numerous, and rapidly recorded measurements. These measurements are used for complex calculations to analyze the engine's operation, and the results must be known very quickly. To satisfy these requirements, the PTC installed an automatic measurement system controlled by a computer.

A primary system of data acquisition and real-time calculation was installed in 1968 and expanded progressively up to the present. Its heart is an IBM 1800 industrial computer, which is linked by cables to the test stations. During a test,

the various engine parameters to be measured are transformed on the spot into electric impulses by transducers. These electric impulses, sent along cables to the computer, are read and arranged in memory each time the engine's schedule reaches a stabilized stage. An interpretation program then executes the required calculations (mainly on the engine's performance) and sends the results back to the station to a receiver which can be a printer, a viewing screen, or a recorder. Measurements are taken and calculations are done immediately, i.e. the testing engineers and technicians know the performance of their engine with a delay of less than a minute.

The data placed in memory remain filed and available for more complete subsequent calculations, establishing statistics, making tables and charts, etc.

This system does, however, have a certain number of inconveniences:

- excessive centralization leads to restrictions in operation at the level of the stations: shutdown in case of a breakdown, computer overload;

- the equipment is becoming obsolete.

STRATOS

It was thus decided to install a <u>second generation</u> of computers and acquisition lines, making up the STRATOS system.

A decentralization option determined the choice of the system: it is presented as a star-shaped network whose heart is a Mitra 125 from the Compagnie Internationale pour l'Informatique [International Computer Company].

At the end of each branch is a Mitra 15 or a Mitra 127, which assures transmission of acquired measurements and calculations for a sub-assembly of 1 to 4 stations. It is connected by a high-speed link to the central computer.

The local calculation capacity will make it possible to generalize rapidly acquired measurements (transitory phenomena) and to continuously observe the machines (alarms, procedure).

ICING TESTS /10

Meeting icing clouds is a great danger for aircraft. Various methods prevent or eliminate ice deposits. The ability of an engine to operate in these clouds must be demonstrated in order to obtain authorization for private use (certification).

Two stations at the PTC are equipped to conduct icing tests in simulated flight (R2 and R6). The equipment includes a jet which supplies cold and very humid air, in which very fine droplets of water (20 microns) are pulverized to form the ice cloud.

The equipment to be tested is observed by television, filmed and photographed. It is even possible to collect the ice formed and weigh and measure it.

The pulverization grid of the R6 has 470 injectors controlled by 2 circuits of water and 3 circuits of air. Linked to a 2-m jet, it permits certification tests for the Mercury engine nacelle.

ENVIRONMENT TESTS

With the "cold hangar" in the A07 station, the PTC has an interesting method of studying performance in heat (+50°) or cold (-45°), not only of engines but also of complete vehicules--helicopters, aircraft, trucks, assault vehicules, climatized cabs, etc.--using a 1000-m^3 chamber connected to the installations in building A.

In another area, "noise chambers" make it possible to subject rocket and satellite equipment to very intense noise (155 dB).

METALLURGY LABORATORY /11

The materials used in aeronautics, especially metals in the form of high-resistance alloys, are the object of numerous analyses and characterization tests designed either to define their possibilities or to control their qualities if problems appear during utilization. The Metallurgy Laboratory of the PTC is equipped to analyze the composition of metals, to identify them, to examine them under an electron microscope, and to determine under what conditions they will break.

An important phenomenon is metal fatigue. Several machines make it possible to form test pieces according to charging cycles (oligocyclic fatigue) in heat or cold so that the rupture occurs after a relatively low number of cycles.

INSTRUMENTATION LABORATORIES

The measurements taken by computer are obtained by "chains" with a transducer which emits an electric signal as a function of the amount measured. These transducers are in general supplied

at very stable voltages; the signal must be amplified before it is used for recording or viewing.

The transducers and also the amplifiers must be adjusted and calibrated regularly to assure precise measurements.

All the elements of the chains (commutators, meters, etc.) must be carefully received just like the control devices themselves, fixed or portable.

The principle measurements made at the PTC concern pressure, temperature, gas composition, flow, and voltage.

In addition, certain complex adaptation devices are put together on the spot, such as the pressure "slides" or the alarm systems.

A17 SOUNDPROOF CHAMBER /12

Since 1966, the PTC has been equipped to analyze noise emitted by jet engines, represented by models for obvious reasons. The A17 station is essentially a 600-m^3 circuit isolated by construction from exterior noise (floating stone) and covered on the inside with a coating which absorbs sound waves above 200 Hz.

An autonomous compressor supplies the air which, heated by propane combustion, simulates the jet engine in 1/10 scale models.

While the Concorde was being tested, this station did more than 1300 hours of testing per year. Although subsequent development tests must be done mostly in the CEPRA wind tunnel, basic analyses keep the A17 chamber occupied in a worthwhile

manner. In addition, transformation into a compressor station is being studied.

TURBOJET STATION

Turbojets (station T6) and turboprops (HO station) are the object of exceptionally prolonged endurance tests corresponding to their private use. The PTC studied, designed, and built equipment for automating these endurance tests, which are therefore faster, more reliable, and can be conducted outside of normal working hours; the personnel is required to do fewer repetitive tasks.

"B.B.O." COMPRESSOR GROUP /13

This group of machines unites all the functions of the "atmospherization" machines for flight simulation tests.

It includes:

- an 7000-kW electric motor supplying a low-pressure compressor (BD), a medium-pressure compressor (MD), and an expansion turbine (TD);

- a second identical motor supplying a high-pressure compressor (HD).

In the BD + MD configuration, air suction at very low pressure (a few hundredths of an atmosphere) is possible.

Using the two motors in MD + HD form, it is possible to supply air at under 25 atmospheres for combustion chambers (after heating to 650°).

Finally, with MD + TD, it is possible to obtain very cold air (-40°C).

BOILER ROOM II

The largest portion of the PTC's mechanical power is obtained from steam produced on site. Boiler room II includes 2 generators producing 100 tons of steam per hour each (fuel consumption 8 tons per hour). These boilers were built in 1934 for a "Montcalm"-type cruiser. A superheater is necessary to bring the steam to the same conditions as that produced by Boiler room I (400°C, 25 bars).

To reduce heat loss, burners added in 1976 maintain a certain temperature during the night.